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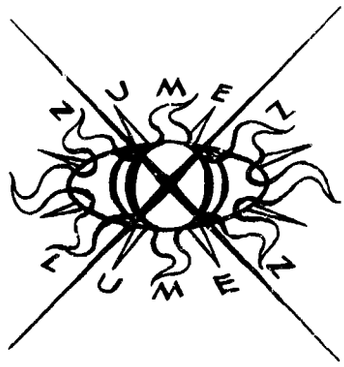

BLIOGRAPHY OF EXPERIMENT DESIGN 1950-1967

W. T. Federer and L. N. Balaam

MRC Technical Summary Report # 1080
October 1971

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13. ABSTRACT

A classification system for publications on the design and analysis of experiment and treatment designs has been devised. Publications on experiment design, the arrangement of the treatments in the experiment, have been classified accordingly and cover the period 1950-1967 inclusively.

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ABSTRACT

A bibliography consisting of approximately 1700 literature citations on the various aspects of experiment design (the arrangement of treatments in the experiment) is presented for the years 1950 to 1967, inclusive. A classification system for experiment designs, for treatment designs (the selection of treatments included in the experiment), and for topics on the philosophy, technique, conduct, and analyses of experiments, is described. Each literature citation in the bibliography is coded in the manner indicated by the classification system. Papers on the theoretical, applied, and practical aspects of experiment design are included.

BIBLIOGRAPHY OF EXPERIMENT DESIGN, 1950-1967

by

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and

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I. INTRODUCTION

Publications on the various aspects of experiment design (the arrangement of the treatments in a comparative experiment) and the treatment design (the selection of the treatments included in the experiment) have become numerous during recent years. Thus, searching the literature for papers on a particular topic is a difficult task which can be considerably alleviated by a comprehensive bibliography, especially if a classification is included. The general statistics bibliographies by Kendall and Doig [1962, 1965, 1968] are helpful in this connection. However, bibliographies on specific topics are even more useful. This was the reason for the previous bibliography prepared by Federer [1964]; this work covered published literature on the design, conduct, and statistical analyses of experimental investigations prior to 1950; no classification of citations was presented although a partial classification was presented in the textual part of the report.

The present bibliography contains about 1700 literature citations on experiment design for the years 1950 to 1967, inclusive. A classification of experiment designs is given in the second section of the paper. Since many of the publications are concerned with topics in addition to experiment design, they are further classified

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into the categories described in sections III and IV. In section III a classification of treatment designs is presented, and in section IV a classification of various statistical analyses and of other aspects of experiment and treatment designs is given. Bibliographies on the subjects of sections III and IV have been prepared and are to be published in a book, together with the present bibliography and a revised version of the pre-1950 bibliography prepared by Federer [1964].

The classification system utilized was to first classify a paper as to whether it was chiefly on experiment (experimental) design as E, on treatment design as T, on analyses of experiments as A, on the general conduct of experiments or on special topics as C, on bibliographies as related to the design and analysis of experiments as B, and on sequential and fixed sample size procedures as S.

Under each of the main categories of classification as listed above, numbers $1,2,\ldots,\leq 15$ were used to divide a category into subclasses. A third category of classification was to classify a paper as to whether it was on the general conduct, on the application, or on the analysis for an experiment or a treatment design, which was coded a, whether it was on the construction procedure for an experiment or a treatment design, which was coded c, or whether the paper contained a numerical example of an experiment or treatment design which was coded e; this sub-subclassification was utilized for the E and T classifications but not for the A, B, C and S classifications.

As with all bibliographies some references have been omitted accidently and some publications containing articles on the design and analysis of experiments did not come to the author's attention. Also, the searching was done mostly by title with some searching being done from summaries or abstracts. In the latter case the reference and the checking of the citation came from the abstract. The references at the end

of an article were scanned to determine if any should be included. Quite often an entire volume was scanned if it contained one or more appropriate articles for the bibliography. The following journals were searched in their entirety for references to be included. The abbreviation listed on the right is used in the bibliography. The listing is in alphabetical order, omitting articles and prepositions from the title. (Several additional journals were partially or completely searched. Some of those completely scanned were omitted from the following list because they did not include papers on experiment and treatment design.):

Agronomy Journal, Vol.42 (1950) to Vol.59 (1967) (U.S.)	Agron. J
American Society for Quality Control, Technical Conference Transactions, ninth (1955) to twenty-first (1967) (U.S.)	ASQC, Tech. Conf. Trans.
The American Statistician, Vol.4 (1950) to Vol.21 (1967) (U.S.)	Amer. Stat.
Annals of the Institute of Statistical Mathematics, Vol.2 (1950) to Vol.19 (1967) (Tokyo, Japan)	Ann. Inst. Stat. Math.
The Annals of Mathematical Statistics, Vol.21 (1950) to Vol.38 (1967) (U.S.)	AMS
Applied Statistics, Vol.1 (1952) to Vol.16 (1967) (Great Britain)	Appl. Stat.
Australian Journal of Agricultural Research, Vol.1 (1950) to Vol.18 (1967) (Australia)	Australian J. Agri. Res.
The Australian Journal of Statistics, Vol.1 (1959) to Vol.9 (1967) (Australia)	Australian J. Stat.
Biometrics, Vol.6 (1950) to Vol.23 (1967) (International)	Biometrics
Biométrie-Praximétrie, Vol.1 (1960) to Vol.8 (1967) (Belgium)	Biométrie-Praximétrie
Biometrika, Vol.39 (1950) to Vol.54 (1967) (Great Britain)	Biometrika
Biometrische Zeitschrift, Vol.1 (1959) to Vol.9 (1967) (Germany)	Biom. Zeit.
Bragantia, Vol.10 (1950) to Vol.26 (1967) (Brazil)	Bragantia

The British Journal of Statistical Psychology, Vol.1 (1950) to Vol.19 (1966) (Great Britain)	British J. Stat. Psychology
Bulletin of the Calcutta Mathematical Society, Vol.42 (1950) to Vol.57 (1965) (India)	Bull. Calcutta Math. Soc.
Bulletin de l'Institut International de Statistique, Vol.32 (1950) to Vol.41 (1966)	Bull. ISI
Bulletin of Mathematical Statistics, Vol.4 (1950) to Vol.12 (1967) (Fukuoka, Japan)	Bull. Math. Stat.
Calcutta Statistical Association Bulletin, Vol.2 (1950) to Vol.16 (1967) (India)	Calcutta Stat. Assoc. Bull.
Canadian Journal of Mathematics, Vol.2 (1950) to Vol.19 (1967) (Canada)	Canadian J. Math.
Comptes Rendus, Des Séances de l'Académie des Sciences, Paris, Vol.230 (1950) to Vol.265 (1967) (France)	Comptes Rendus
Crop Science, Vol.1 (1961) to Vol.7 (1967) (U.S.)	Crop Sci.
Current Science, Vol.19 (1950) to Vol.36 (1967) (India)	Current Sci.
Der Züchter, Zeitschrift für theoretische und angewandte Genetik, Vol.20 (1950) to Vol.37 (1967) (Germany)	Der Züchter
Estadística, Journal of the Inter-American Statistical Institute, Vol.8 (1950) to Vol.25 (1967)	Estadística
Euphytica, Journal of Plant Breeding, Vol.1 (1952) to Vol.16 (1967) (Netherlands)	Euphytica
Dissertation Abstracts, Vol.10 (1950) to Vol.27 (1967) (U.S.)	Dissertation Abs.
Genetical Research, Vol.1 (1960) to Vol.10 (1967) (Great Britain)	Genetical Res.
Heredity, Vol.4 (1950) to Vol.14 (1960) (Great Britain)	Heredity
Industrial and Engineering Chemistry, Vol.42 (1950) to Vol.59 (1967) (U.S.)	Ind. Eng. Chemistry
Industrial Quality Control, Vol.6 (1950) to Vol.24 (1967) (U.S.)	IQC
Journal of the American Statistical Association, Vol.45 (1950) to Vol.62 (1967) (U.S.)	JASA

Journal of Combinatorial Theory, Vol.1 (1966) to Vol.3 (1967) (U.S.)	J. Combinatorial Theory
Journal of the Indian Society for Agricultural Statistics, Vol.2 (1950) to Vol.19 (1967) (India)	JISAS
Journal of the Indian Statistical Association, Vol.1 (1963) to Vol.5 (1967) (India)	JISA
Journal of Research of the National Bureau of Standards, Mathematics and Mathematical Physics, Series B, Vol.44 (1950) to Vol.71 (1967) (U.S.)	J. Res. NBS
Journal of the Royal Statistical Society, Series A, (General), Vol.113 (1950) to Vol.130 (1967) (Great Britain)	JRSSA
Journal of the Royal Statistical Society, Series B, (Methodological), Vol.12 (1950) to Vol.29 (1967) (Great Britain)	JRSSB
Journal of Science of the Hiroshima University, Series A-I (Mathematics), Vol.17 (1953) to Vol.31 (1967) (Japan)	J. Sci. Hiroshima Univ. Ser. A-I
Journal of the Society for Industrial and Applied Mathematics, Vol.1 (1953) to Vol.15 (1967) (U.S.)	J. Soc. Ind. Appl. Math.
Mathematics of Computation from 1960, formerly was Mathematical Tables and Aids to Computation, Vol.4 (1950) to Vol.21 (1967) (U.S.)	Math. Tables Aids Comp. or Math. Comp.
Melhoramento, Estudos da Estação de Melhoramento de Plantas, Vol.4 (1950) to Vol.16 (1963) (Portugal)	Melhoramento
Memoirs of the Faculty of Science, Series A (Mathematics), Kyūshū University, Vol.6 (1951) to Vol.21 (1967) (Fukuoka, Japan)	Mem. Faculty Sci.
Methods of Information in Medicine, Methodik der Information in der Medizin, Vol.1 (1962) to Vol.5 (1966) (Germany)	Meth. Inf. Med.
Metrika, International Journal for Theoretical and Applied Statistics, Vol.1 (1958) to Vol.12 (1967) (Germany)	Metrika
Metron, International Review of Statistics, Vol.15 (1950) to Vol.26 (1967) (France)	Metron
Mitteilungsblatt für Mathematische Statistik (became Metrika), Vol.4 (1952) to Vol.9 (1957) (Germany)	Mitteilungsblatt Math. Stat.

Plant Breeding Abstracts, Vol.20 (1950) to Vol.37 (1967) (U.S.)	Pl. Br. Abs.
Proceedings of the American Mathematical Society, Vol.1 (1950) to Vol.18 (1967) (U.S.)	Proc. Amer. Math. Soc.
Proceedings of the American Society for Horticultural Science, Vol.55 (1950) to Vol.91 (1967) (U.S.)	Proc. Amer. Soc. Hort. Sci.
Proceedings of the nth Conference on the Design of Experiments in Army Research Development and Testing, Vol.1 (1957) to Vol.12 (1967) (U.S.)	Proc. Conf. Design Expt. Army Res. Dev. Testing
Proceedings of the kth Berkeley Symposium on Mathematical Statistics and Probability	Proc. kth Berkeley Symp. Math. Stat. Prob.
Psychometrika, Vol.15 (1950) to Vol.32 (1967) (U.S.)	Psychometrika
Publications de l'Institut de Statistique de l'Universite de Paris, Vol.1 (1952) to Vol.16 (1967) (France)	Pub. Inst. Stat. Univ. Paris
Quality Control and Applied Statistics (Abstracts) Vol.11 (1966) to Vol.12 (1967) (U.S.)	QC Appl. Stat.
Reports of Statistical Application Research, Union of Japanese Scientists and Engineers, Vol.1 (1951-2) to Vol.14 (1967) (Japan)	Reports Stat. Appl. Res.
Revue de l'Institut International de Statistique, Vol.18 (1950) to Vol.35 (1967) (International)	Rev. ISI
Revue de Statistique Appliquée, Institut de Statistique Universite de Paris. Vol.1 (1953) to Vol.15 (1967) (France)	Rev. Stat. Appl.
Sankhyā, The Indian Journal of Statistics, Vol.10 (1950) to Vol.29 (1967) (India)	Sankhyā
Statistica Neerlandica (named Statistica prior to Vol.9 1955) Vol.4 (1950) to Vol.21 (1967) (Netherlands)	Statistica or Stat. Neerlandica
Suid-Afrikaanse Tydskrif vir Landbouwetenskap, Vol.1 (1958) to Vol.10 (1967) (South Africa)	Suid-Afri. Tydskrif Landbouwetenskap
Technometrics, Vol.1 (1959) to Vol.9 (1967) (U.S.)	Technometrics

Trabajos de Estadística, Vol.1 (1950) to Vol.15 (1964) — Trabajos Estad.

Zeitschrift für Pflanzenzüchtung, Vol.29 (1950) to Vol.58 (1967) (Germany) — Z. Pflanzenzüchtung

In addition to the above journals the following books and special publications containing a series of papers represent some of the other sources scanned for papers on experiment design:

Biometrical Genetics

Bulletin de l'Institut Agronomique et des Stations de Recherches de Gembloux (Hors Serie) 1960, Volume 1.

Cold Spring Harbor Symposia on Quantitative Biology, Proceedings.

Colloques Internationaux du Centre National de la Recherche Scientifique, No. 10. Le Plan d'Experience.

Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling.

Contributions to Statistics: Presented to Professor P. C. Mahalanobis on the Occasion of his 70th Birthday.

Economic and Technical Analysis of Fertilizer Innovations and Resource Use.

Experimental Designs in Industry.

Heterosis.

Mathematics and Computer Science in Biology and Medicine.

Statistical Genetics and Plant Breeding, NAS.

Statistical Theory of Reliability.

Statistics and Mathematics in Biology.

Stochastic Models in Medicine and Biology.

II. EXPERIMENT OR EXPERIMENTAL DESIGN

In the published literature two terms, experimental design and experiment design, have been utilized to refer to the arrangement of treatments in a comparative experiment. Perhaps the term experiment design is better grammatical form in comparison with the term treatment design. Also, published literature is highly confused on the use of the term experimental design in that this term has been used for almost all statistical aspects of experimentation from the selection or sample size and of treatments to the conduct and analyses of experiments. This would be one reason for discarding the term experimental design and for using the term experiment design.

In general, experiment designs are classified into designs with zero-way, one-way, two-way, etc. elimination of heterogeneity in experimentation. (As may be noted from published literature, e.g. reference 2194, one alternate form of classification is to denote these designs as one-dimensional, two-dimensional, three-dimensional, etc., respectively; other classifications have been devised.) This refers to the type of blocking in an experiment. The categorization can result in some confusion for such designs as the split plot (or the split block) experiment designs and the lattice square experiment design. The latter experiment design is classified as having three-way elimination of heterogeneity, i.e., complete blocks and rows and columns within each complete block. In the split-block design analyses using only one-way blocking are possible. Similarly in a resolvable balanced incomplete block design, an intrablock analysis on treatments and residual is possible without considering the fact that complete blocks were designed into the experiment.

The various subclassifications of experiment designs are listed below as E1, E2, . . . , E14.

1. Zero-way elimination of heterogeneity — E1

   i) completely randomized design including experiments for which the treatments may be grouped in various ways.

2. One-way elimination of heterogeneity — E2

   i) balanced
      -randomized complete block
      -balanced incomplete block, both resolvable and nonresolvable.

   ii) partially balanced — E3
      -circular
      -cyclic
      -group divisible
      -rectangular lattices
      -right angular
      -triangular
      -2, 3, . . . , n associate class

   iii) other incomplete block designs — E4
      -augmented
      -calibration
      -chain block
      -direct product
      -extended incomplete block
      -linked block
      -reinforced
      -repetitions of designs with same treatments
      -slipped block
      -staircase
      -star
      -unequal block sizes
      -unequal replication on treatments

   iv) others — E5
      -blocking on a trend or gradient
      -constrained randomization
      -n-ary
      -rotation and other serially correlated
      -simple changeover
      -simple multiresponse
      -split plot (whole plots in a completely randomized design)
      -supercomplete
      -systematic

v) missing, mixed-up, or damaged experimental units (plots) — E6

3. Two-way elimination of heterogeneity

i) row-column designs — E7
- -gradients within blocks for designs with one-way elimination of heterogeneity
- -latin square and generalized latin square
- -simple change-over
- -tied-latin squares
- -Youden square and extended Youden square
- -other latin rectangle or row-column

ii) row-column designs to measure residual effects — E8
- -double change-over
- -rotation
- -tied double change-over

iii) others — E9
- -augmented
- -balancing in two groups
- -direct product
- -multivariate hierarchical
- -nested balance
- -plaid and half-plaid latin square
- -quasi-latin square
- -Trojan square

iv) missing, mixed-up, or damaged plots — E10

4. Three-way elimination of heterogeneity

i) lattice square, lattice rectangle, and latin cube (including missing, mixed-up, and damaged plots) — E11

ii) others — E12
- -augmented
- -graeco-latin square
- -latin cube
- -magic latin square
- -quasi-latin square
- -split block (or criss-cross)
- -split and split-split plot
- -U:VW and U:VW:XYZ plans for two sets of treatments

5. Four and higher-way elimination of heterogeneity E13
   - -hyper-graeco-latin square and cube
   - -lattice square with split plots
   - -t-restrictional lattice
   - -multidimensional
   - -split, split,split... plot

6. Properties of experiment designs E14
   - -balance and partial balance
   - -blocking
   - -efficiency
   - -orthogonality
   - -randomization
   - -replication
   - -sensitivity
   - -others

Each of the above categories (except for E14) were further classified as a, c, and/or e. The a refers to application and/or analysis, the c refers to construction, and the e refers to a numerical example (mostly nonfictitious) for a particular experiment design.

III. TREATMENT DESIGN

Treatment design refers to the selection of treatments in an experiment. Many writers in statistical literature have used the term experimental design or design of experiments in their discussion of treatment designs. This has lead to some confusion. This usage has been especially prevalent in connection with factorial and fractional factorial treatment designs and sample size determinations.

The following classification of treatment designs has been utilized to classify statistical publications:

1. Selection of X values and of the X variables in regression studies. T1

2. Factorial T2
   - -complete factorial
   - -confounding in factorial experiments
   - -mixed and fixed effects excluding variance component analysis
   - -quantity x quality interaction

3. Fractional replication

   i) regular fractions (only complete confounding of effects in aliasing structure) T3

   ii) other fractions T4
   - -response surface, rotatable, central composite, steepest ascent, EVOP, response curves, PARTAN
   - -simplex, vertices, mixtures, constrained T5
   - -weighing T6
   - -others (additional or missing combinations, group testing, random balance, randomized factorials, complementation, screening X-variables) T7

   iii) Dosage response (sequential and fixed) T8

   iv) Genetic (diallel crossing systems, parents and crosses, other genetic treatment designs) T9

v) Paired, tripled, . . . , k comparisons T11

4. Properties T10
   - -aliasing
   - -balance
   - -invariance
   - -minimum variance, trace, determinant, etc.
   - -orthogonality
   - -rotatability
   - -unbiased

As with experiment designs, the treatment design categories (except T10) were further subdivided into the a, c, and e, where these symbols have the same meaning as for experiment designs.

IV. TOPICS RELATED TO THE CONDUCT OF EXPERIMENTS AND ON THE ANALYSIS OF EXPERIMENT AND TREATMENT DESIGNS

A complete coverage was attempted for statistical publications, including special mimeograph series and theses on experiment and treatment design. The coverage of statistical literature for the A, B, C, and S categories was not complete; publications relating solely to properties of statistical procedures were omitted. The selection of topics was arbitrary, with variance component analyses, properties of statistical procedures, time series and regression analyses in economics, sample survey design, and chi-square analyses being excluded. The topics included were those considered to be of most importance in the analysis of experiments. The topics included and the classification symbols follow:

1. Analysis and some aspects of experimentation

i)	error rates	A1
ii)	ranking procedures (ordering of treatment means, tournaments, picking a winner, screening; see also S2.)	A2
iii)	multiple range and simultaneous confidence interval procedures	A3
iv)	nonadditivity of effects	A4
v)	randomization and permutation tests	A5
vi)	outliers, extreme values, stragglers, runs, residual analyses	A6
vii)	covariance and multivariate analyses including growth curves and nonlinear regression	A7
viii)	calculus of factorials and direct products	A8
ix)	transformation of data	A9
x)	unequal numbers procedures	A10

xi) heterogeneity, pooling, and combining variances, Behrens-Fisher procedures, and random sample size — A11

xii) distribution free procedures — A12

xiii) summarization of results from groups of experiments, allocation of resources and units to various categories, long term experiments — A13

xiv) miscellaneous topics (plot size and shape, uniformity trials, Kronecker products in statistical analysis, cumulants and polykays, plant density, competition, border effect, experimental controls, subsampling, random versus systematic arrangements, vector analysis) — A14

xv) computer programs for analyses of experiments — A15

2. Sample size

i) fixed — S1

ii) sequential sampling and sequential experimentation — S2

3. Conduct and philosophy of experimentation and special procedures (general conduct, grouping experiments, clinical trials, survey of experimentation, measurement of tastes and threshholds, data analyses including jackknife procedures) — C

4. Bibliography (main purpose of paper was to present a bibliography or if a good bibliography was attached) — B

No further subdivision of the above categories was made.

It should be noted that some categories have much in common; for example, many papers listed under A2 are concerned with determining sample size, some papers in A7 are concerned with long term experiments, and some papers in A13 are concerned with allocation of samples within various strata.

V. FORM OF THE BIBLIOGRAPHY

References on experiment design are listed first in alphabetical and then in chronological order. Each reference carries a code, such as for example E3c; T2a; A12, which classifies the article in regard to its main content; the references are numbered from 2001 to 3683. Publications with no code or an incomplete code were those cited in another paper but for which the original paper or an abstract could not be found to verify the citation or the classification and were those which were considered to be important to list in the bibliography either because of the importance of the paper or because of the journal or language in which it was published. All doctoral theses are listed as "Ph.D. Thesis"; it should be noted that some of these are doctor of science theses.

The entire bibliography, which is to be published elsewhere, is divided into five parts with one part being devoted to literature citations relating to experiment design. This part is given here. Theses and mimeographed, multilithed or photo-offset series are included. A second part of the bibliography will be devoted to literature citations on treatment design including theses and special series. Some of the references in the part on experiment design will be duplicated in the part on treatment design.

A third part will contain references related to the analysis of experiment and treatment designs, to the conduct of experiments, to the general philosophy of experimentation, to sample size considerations, or to other special topics. No references with an E or a T classification will be duplicated in the third part of the bibliography. The reason for this is that the emphasis is on a bibliography for experiment design and for treatment design. The third part is considered to be supplementary to the first two parts.

The fourth category or part of the bibliography will be concerned with books devoted mainly to experiment and/or treatment design. The books in this category could be considered as texts for a course or series of lectures on experiment and treatment designs. Such a requirement eliminates a large number of textbooks on statistical methods which contain some material on these topics. An attempt will be made to determine the dates of printings and editions of a particular book. In addition an attempt will be made to ascertain all reprintings of a book and the language in which the reprinting was made.

A fifth part will include pre-1950 literature citations on the design, conduct, and analyses of experiments; this will be a revised version of Federer [1964]. At the end of each part a list of co-authors is given.

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